INVESTIGATIONS OF STRESS STATE IN SOIL UNDER TRACTOR TYRES

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INTRODUCTION

Soil stress state is the effect of external loads applied to soil surface by wheels of agricultural tractors and machines. There are a number of theories [5, 6, 7] on soil stress state and its influencing parameters. Those models, however, suffer from lack of accurate experimental data for verification [8]. Soil stress determination is a difficult problem and several solutions have been applied [2, 9, 10, 15]. In general, there are methodological problems arising from the properties of soil, which is a three phase, granular medium [7, 9, 12]. Moreover, the mechanical properties of soil change significantly when soil conditions are changing. Consequently, the use of standard methods for pressure measurements is erroneous and special techniques are required [1, 12].

One of those methods is a determination of soil stress state with the use of the SST (stress state transducer) [11, 13, 14]. First introduced by Bailey et al, 1987 [1], the device consisting of six pressure transducers has become nearly standard equipment in soil mechanics, especially in soil-wheel interaction studies. The SST enables to capture soil pressures (Fig. 1), which are then used for soil stress calculations. Basic equations are as follows:

Pressure transducers are a special concern in soil stress investigations. A number of researchers dealt with the problem [3, 4, 7, 16, 17] and various transducer types were in research and practical use. They can be categorized into three groups: hydraulic transducers with intermediate liquid [4, 17], pneumatic transducers [3] and strain gage type transducers [1, 7, 9, 16]. The first two types are deformable devices. Bailey, 1987 has given a set of design requirements for a proper strain gage pressure transducer for soil. Pytka 1998 has studied several factors influencing the action of a strain gage type transducer in different soils and other granular materials [12].

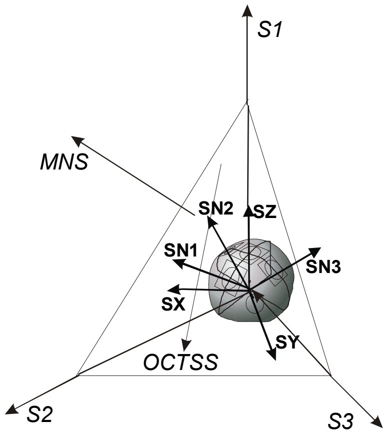

Fig. 1. Stress state components and the geometry of the SST

The pressure transducers built into the existing SST are integrated with micro-instrumentation amplifiers, which is of great importance for proper data acquisition.

The aim of the present study was to examine the developed stress state transducer in field experiments with agricultural vehicles in real conditions.

MATERIALS AND METHODS

In the experiment a 29 kW agricultural tractor of the total mass 2450 kg was used. Front wheel load was 880 kg and rear wheel was loaded with 1630 kg of mass. The tractor was equipped with tyres as follows: front tyres: rear tyres. The vehicle was driven for several times over the region of the investigated soil with the longitudinal speed of about 4-5 km/h (see Fig. 2). The right front and rear wheels have overdriven the region of soil where the transducer was installed. It was of a special care to drive the tractor wheel exactly over the transducer.

Fig. 2. A test ride of the tractor used in the experiment

Soils on which the experiments were conducted were: sandy soil of 1.70 g/cm^3 bulk density and loess soil of 1.63 g/cm^3. The soils have not been especially conditioned before the tests. A stress state transducer was installed at the depth of 15 and 30 cm. The tractor has performed up to six passes over the same rut and between the passes no operations were applied to soil.

RESULTS AND DISCUSSION

A typical stress state graph for two depths of SST installation is presented in Fig.3. Here we have type dependent (or wheelposition dependent) stress components curves for major stresses – S1, S2 and S3 as well as for octahedral stresses: MNS and OCTSS (mean normal stress and octahedral shear stress respectively). Apparently the stress values are smaller for deeper installation of the transducer. This proves the expectations of stress distribution in soil: the deeper in soil the smaller the stress is. This was mathematically described by Boussinesq and Frohlich, who added the so called stress concentration factor. The highest is the major stress S1, the S2 and S3 stresses reach considerably smaller values in peaks. This would suggest the assumption of heterogeneous stress state in soil. The difference between sandy and loess soil is less significant.

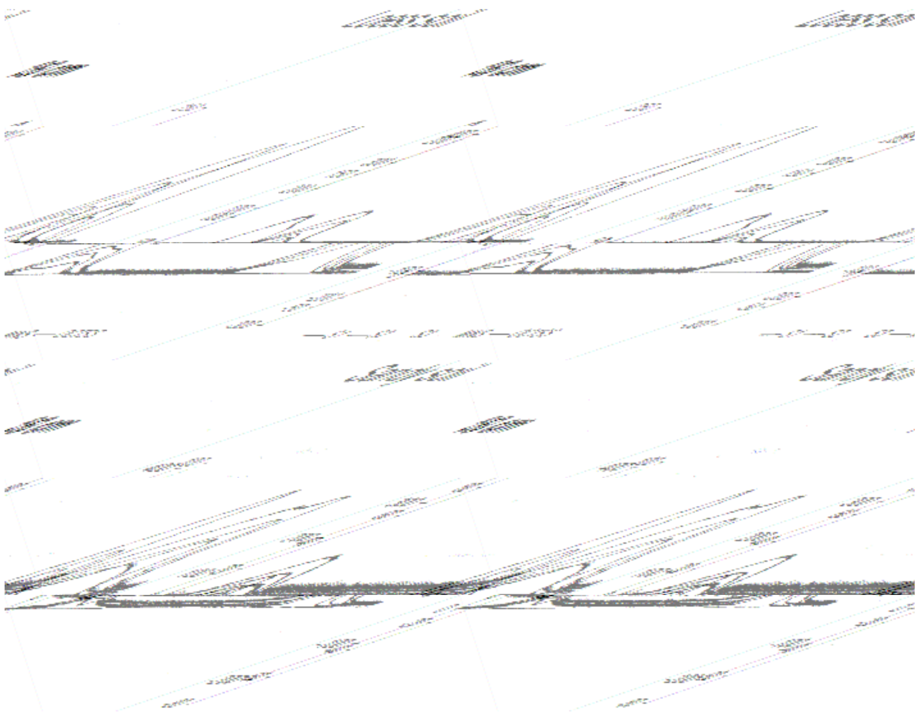

Fig. 3. Stress state components for two soils and two measurements depths

The effect of multiple passing on stress state is graphically shown in Fig. 4. Here we can see the first two or three passes are of the highest importance. The increase of stress values at the peak is significantly greater between the first and the second than between the second and the third pass.

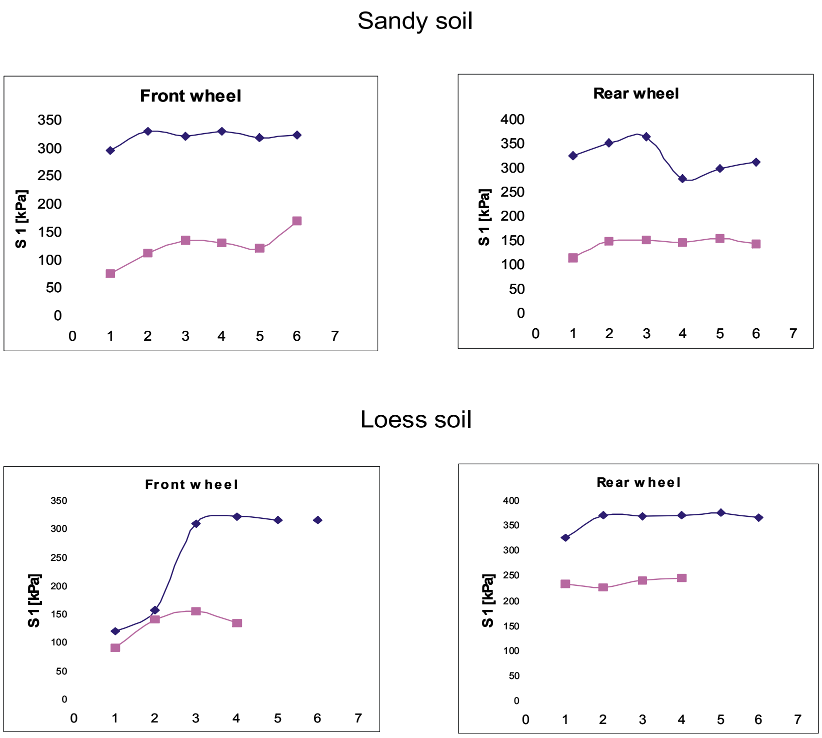

Fig. 4. Effects of multiple passes on major stress S1 in sandy and loess soils

Further passes caused a considerably smaller increase of stress values. It also occurred that the stresses captured under the fourth or fifth passes reached smaller values than those under the second or third. This could be explained as an effect of soil consolidation after several passes over the same rut.

CONCLUSIONS

Stress state in two soils: sandy and loess was determined in field experiments with the use of a 29 kW agricultural tractor. Stresses were measured at two depths: 15 and 30 cm with the use of SST (stress state transducer). It was generally concluded that the developed stress transducer meets the design requirements and is sensitive enough to capture effects of factors as the depth of measurements, external load, soil type.

Based upon the analysis of soil stress data it was assumed that the stress values decrease with the depth of measurements and they increase for the repeated passing of the vehicle.

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SUMMARY

Soil stress state, i.e. major stresses S1, S2 and S3, mean normal and shear stresses on the octahedral plane were determined from soil pressure data captured during a pass of a tractor. To obtain soil pressures a SST (stress state transducer) was used. This device consists of six pressure transducers, which are oriented to measure mutually orhtogonal pressures, needed for the calculations of stress state components. A 29 kW agricultural tractor of the total mass 2450 kg was used in the experiment. The tractor was driven several times over the investigated soil area and the effect of multiple passing was also investigated. The SST was installed at the depth of 15 and 30 cm by simple excavation of soil and then refilling to obtain initial bulk density. Stress state components have been presented in a graphical form. Stress values, effects of multiple passing as well as methodological aspects of the experiments were discussed.